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The Use of Artificial Intelligence in Higher Education: Bibliometric Analysis 2014-2023

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ABSTRACT

Artificial Intelligence (AI) has brought unprecedented growth and productivity to every socioeconomic sector. The application of AI in education is transformational, encompassing the reduction of teacher workload, individualized learning, intelligent tutoring, profiling and prediction, high-precision education, collaboration, and learner tracking. This paper highlights the directions of AI research in higher education (HE) through bibliometric analysis. We adhered to the PRISMA guidelines to select 1610 articles published in the Scopus database between 2014 and 2023. VOSviewer was employed for visualization, and text mining was utilized to identify hotspots in the field. Spain, the United States, the United Kingdom, China, and India dominate the publications. Articles on this topic are predominantly published in conference proceedings and journals. Four themes emerge: data as a catalyst, AI development, AI implementation in higher education, emerging trends, and the future of AI in higher education. This research contributes to the literature by synthesizing opportunities for AI adoption in higher education, topic modeling, and future research areas.

Keywords: Artificial intelligence; Higher education; Technology; Digital transformation; Literature review; Scopus; Bibliometric; PRISMA.

1. Introduction

Profound changes have swept through our world with technological advancements and the increased use of information as the foundation for decision-making in recent decades. This transformation has sparked the emergence of the knowledge economy era. One primary driver of this change is the presence of Artificial Intelligence (AI), which has significantly influenced various aspects of our lives, including lifestyles, the workplace, communication, and the education system (Zemel et al., 2013). The computer science and engineering field focuses on simulating and imitating intelligent human behavior by applying theories, models, and applications to enhance decision-making processes (Naqvi, 2020).

AI automates tasks commonly performed by humans, such as voice and image recognition, drone deployment, stock trading, agriculture, engineering, and manufacturing (Maphosa, 2023). The integration of AI in education has improved decision-making abilities for students through access to e-books, simulations, and virtual reality. The development of AI technology and its implementation in the education sector continues to evolve, offering promising potential (Zhang & Aslan, 2021). Furthermore, research related to the application of AI in higher education (HE) is steadily increasing, as evidenced by previous studies (Chatterjee & Bhattacharjee, 2020; Popenici & Kerr., 2017; Zawacki-Richter et al., 2019).

In the global economy, AI-based technology is applied to accelerate development. It has become a part of the national strategies of leading economies such as the United States, China, Korea, and Japan (Abbas et al., 2019). The United States and China lead the one trillion-dollar investment in AI with values of $694 billion and $185 billion, respectively (Mou, 2019). Billions of dollars are poured into start-ups to implement various AI-based technologies worldwide. These economically significant countries also led investments in AI technology in 2018, with the United States allocating $9.7 billion and China spending $7.4 billion (Daws, 2019). The common goal of

AI is to create machines capable of thinking and performing tasks that require human intelligence, learning, decision-making, and adapting to changes like humans (Christie & Graaff., 2017).

Artificial Intelligence (AI) 's impact in education is highly significant, with industry experts projecting a growth of 43% in 2022 (Alexander et al., 2019). According to Zawacki-Richter et al.'s (Zawacki-Richter et al., 2019) report, educational institutions and governments show increased interest in adopting AI technology in the context of education. Research on AI-based applications in education has experienced rapid development in recent decades. Precision learning approaches supported by AI are gradually replacing traditional, universally applied education models. This approach considers individual differences among learners and specific learning environments, predicting student performance and providing timely interventions to optimize learning (Tsai et al., 2020). Saravanakumar (Saravanakumar, 2019) highlights that AI facilitates individualized learning and helps determine the most suitable learning times for each individual based on their characteristics.

Most research on Artificial Intelligence (AI) in higher education (HE) is conducted in developed countries, as many developing countries are still in the early stages of exploring this research. Higher education institutions' effective use of AI serves as the foundation for socio-economic growth, alongside implementing AI-based technology in various industries and organizations. Research covering AI in the HE field has experienced steady growth, making this bibliometric analysis aimed at evaluating the status, trends, and potential future research topics. This research expands on previous work presented at a conference by Maphosa and Maphosa (Maphosa, V., 2021), which can be considered a mini-review providing an overview of AI research in HE. This bibliometric analysis uses various tools to assess the status, trends, significant contributors, and emerging focus areas.

The implementation of AI in higher education can pose several ethical challenges. According to Khosravi et al (Khosravi et al., 2022), AI tools and technologies exceed their application boundaries in social and even legal aspects, leading to public distrust. Appropriate security measures must be taken to protect student data, including personal information and educational profiles, from commercial exploitation (Pardo & Siemens., 2014). Currently, there are limitations in guidelines, frameworks, policies, and regulations that can address issues related to using AI tools in education (Holmes et al., 2018). Ethical questions arise when teachers use facial recognition systems to monitor student behavior and participation in class activities (Zawacki-Richter et al., 2019). Explainable AI (XAI) can be a solution to alleviate concerns about fairness, accountability, transparency, and ethics in AI use. XAI aims to develop AI systems that can explain their workings to end-users, promoting transparency, interpretation, and trust (Maphosa, 2023).

1.1. Study Objectives

This research involves bibliometric analysis and topic modeling of Artificial Intelligence (AI) research in higher education (HE) over the last decade (2014–2023). In this context, we examine publication and citation trends, the geographic distribution of articles, major subject areas, h-index analysis, and keyword analysis. The study aims to answer the following questions: (1) What research focuses on AI in HE from 2014 to 2023? (2) Which countries and publishers contribute to this discipline? (3) Which AI research centers in HE are the most significant? So this research aims to:

1. Analyze the research focusing on AI in higher education from 2014 to 2023.

2. Analyze which countries, publishers, or journals contribute to this scientific discipline.

3. Analyze the author's references and focus on this research's theme.

4. Analyze AI research centers in HE are the most significant.

5. Analyze the contribution of literature on the use of AI in higher education.

2. Methods

The method employed in this research is to comprehensively summarize previously published studies using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The PRISMA guidelines consist of three main stages: identification, screening, and inclusion, as explained by Page et al (Page et al., 2021). The article selection process can be seen in Figure 1.

In October 2023, we searched and collected data from the Scopus database, which is recognized as a comprehensive data source commonly used for bibliometric analysis. Our initial search focused on articles related to artificial intelligence and higher education. Subsequently, we narrowed our search to titles and abstracts containing the keywords "artificial intelligence" and "higher education," resulting in the selection of 1840 articles.

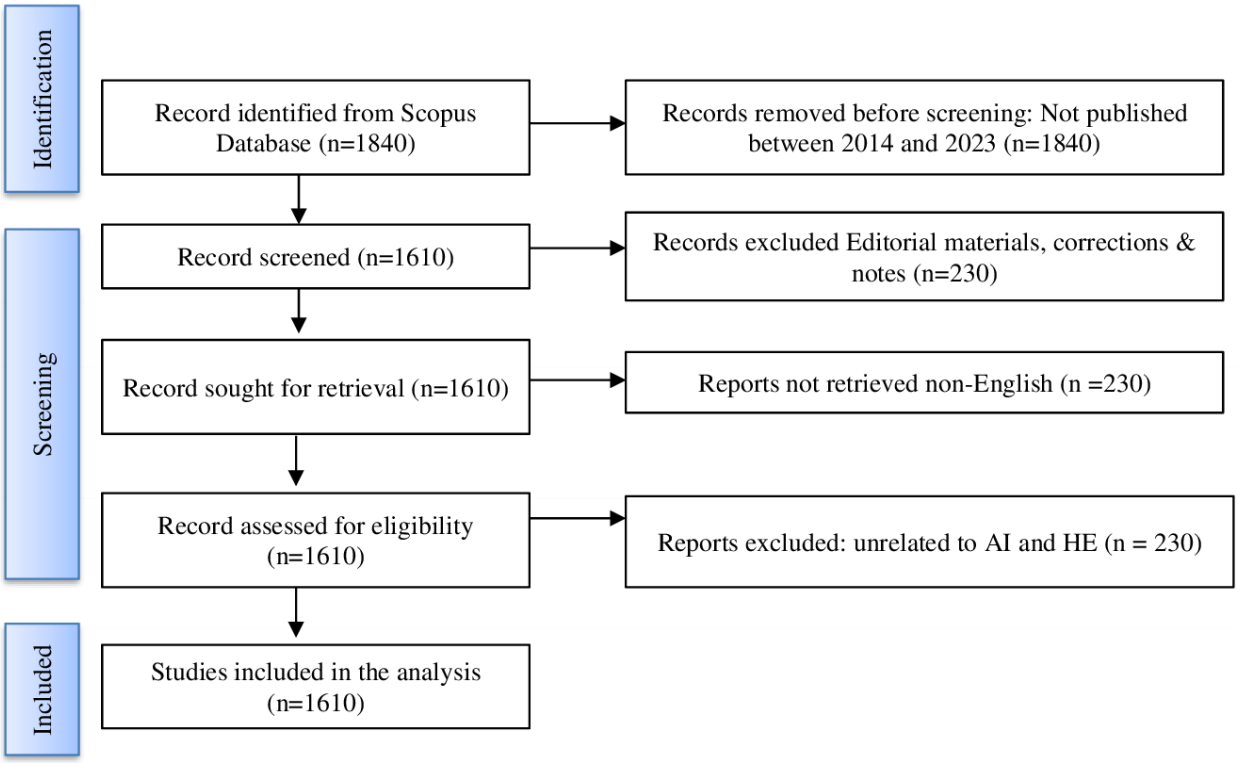

Figure 1. PRISMA flowchart (adapted from Page et al. 2021, (Page et al., 2021))

The research outcomes were focused on articles published between 2014 and 2023, yielding 1610 articles that met the inclusion criteria. We then categorized the articles by type, including conference proceedings, journal articles, and reviews, ensuring that all were in English. This refinement stage led to the exclusion of 230 articles, leaving

1610 articles for further analysis. All articles and their abstracts were exported to MS Excel for in-depth analysis. The article selection process can be seen in Figure 1. Data was obtained from the Scopus database and downloaded in CSV Excel format.

Next, abstracts, keywords, citations, and bibliographic information were exported to VOSviewer, a free bibliometric tool with visualization and text analysis capabilities. VOSviewer can generate network visualizations and density maps (van Eck & Waltman., 2010). Integrated analytical functions provided by the Scopus database and facilitated direct data export to VOSviewer and Excel. VOSviewer created network visualizations and density maps (van Eck & Waltman., 2010). The data analysis process was conducted quantitatively to identify the main themes and trends reflected in the publications.

3. Result and Discussion

The types of documents and the number of articles retrieved are indicated in Table 1. Conference papers comprise nearly half of the analyzed articles; journal articles contribute 41.61%. The dominance of conference proceedings can be associated with the growing presence of AI in higher education and the increasing number of conferences held in this field.

Table 1. Analysis Based on Document Types

Document Types	Total	Percentage
Conference Paper	803	49.88
Article	670	41.61
Conference Review	94	5.84
Review	43	2.67
Total	1610	100

3.1. The Most Productive Country

The researchers employed a minimum of 2 countries per article, resulting in the identification of 89 countries. China and the United States dominate the number of produced documents, and the total link strength for the top 5 countries includes Spain, the United States, the United Kingdom, China, and India. In comparison, the top 5 document-producing countries are China, the United States, India, Spain, and the United Kingdom.

Table 2 presents the tabulation results of the most productive countries for authors of articles on AI in Higher Education, and Figure 2 illustrates their distribution. The geographic distribution of articles indicates an evenly spread research interest in this field across northern and southern regions, although the northern region dominates. There is a noticeable difference in the number of written articles, with countries in the northern region producing more articles than those in the southern region.

Table 2. Top 10 Countries in AI Research in Higher Education

No	Country	Document	Citations	Total Link Strength
1.	Spain	98	836	78
2.	United States	184	1358	75
3.	United Kingdom	90	1165	67
4.	China	228	814	53
5.	India	102	486	47
6.	Saudi Arabia	54	813	45
7.	Portugal	48	326	43
8.	Australia	74	1362	39
9.	Mexico	54	313	35
10.	Germany	58	1077	33

Source: Output VosViewer, 2023

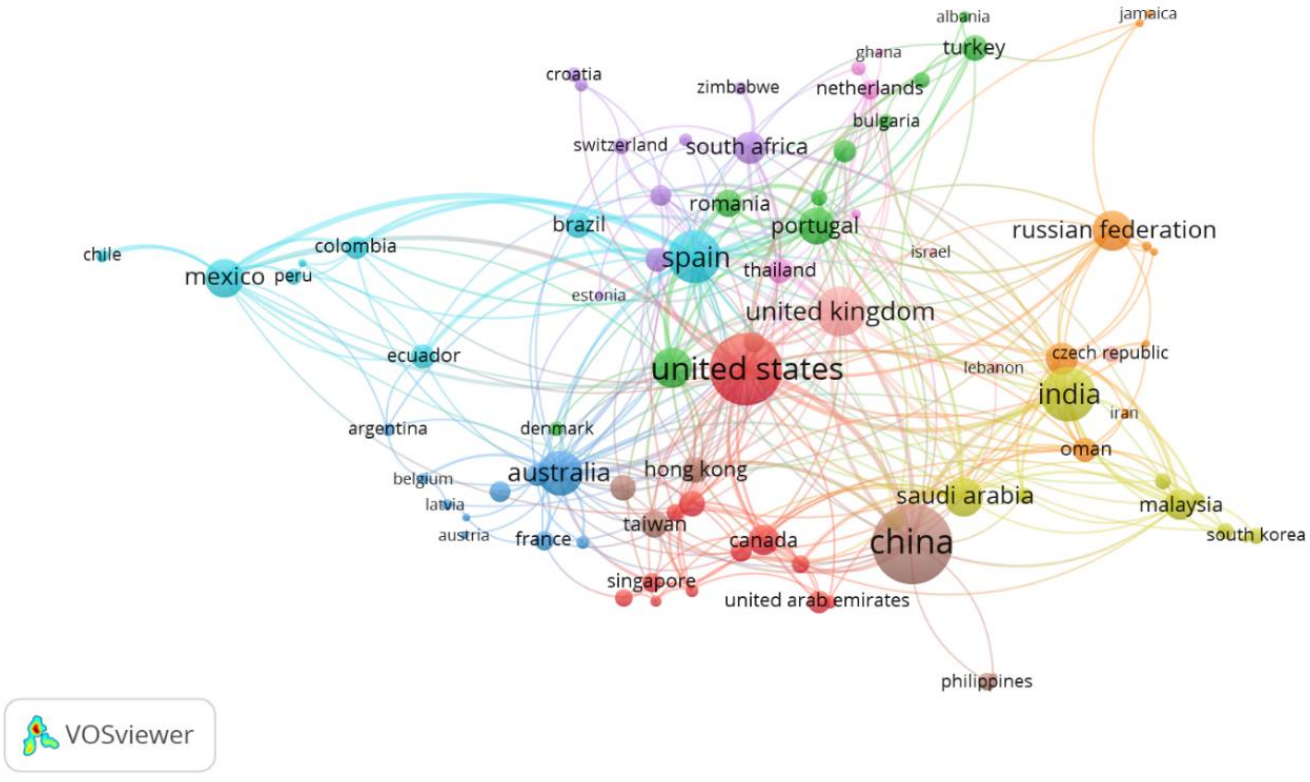

Figure 2. Visualization of Country Networks Based on Number of Documents

3.2. Main Journal Source

From the 1,610 documents, researchers selected a minimum of 3 documents, resulting in 747 journal sources, with 104 interconnected journals. The journal Lecture Notes in Computer Science has the highest number with 77 documents, followed by Advances in Intelligent Systems with 60 documents, ACM International Conference Proceedings with 55 documents, Journal of Physics: Conference Series, Lecture Notes in Networks and Science with 41 documents, and Communication in Computer with 38 documents. Figure 3 displays the visualization of the leading journals on AI in higher education.

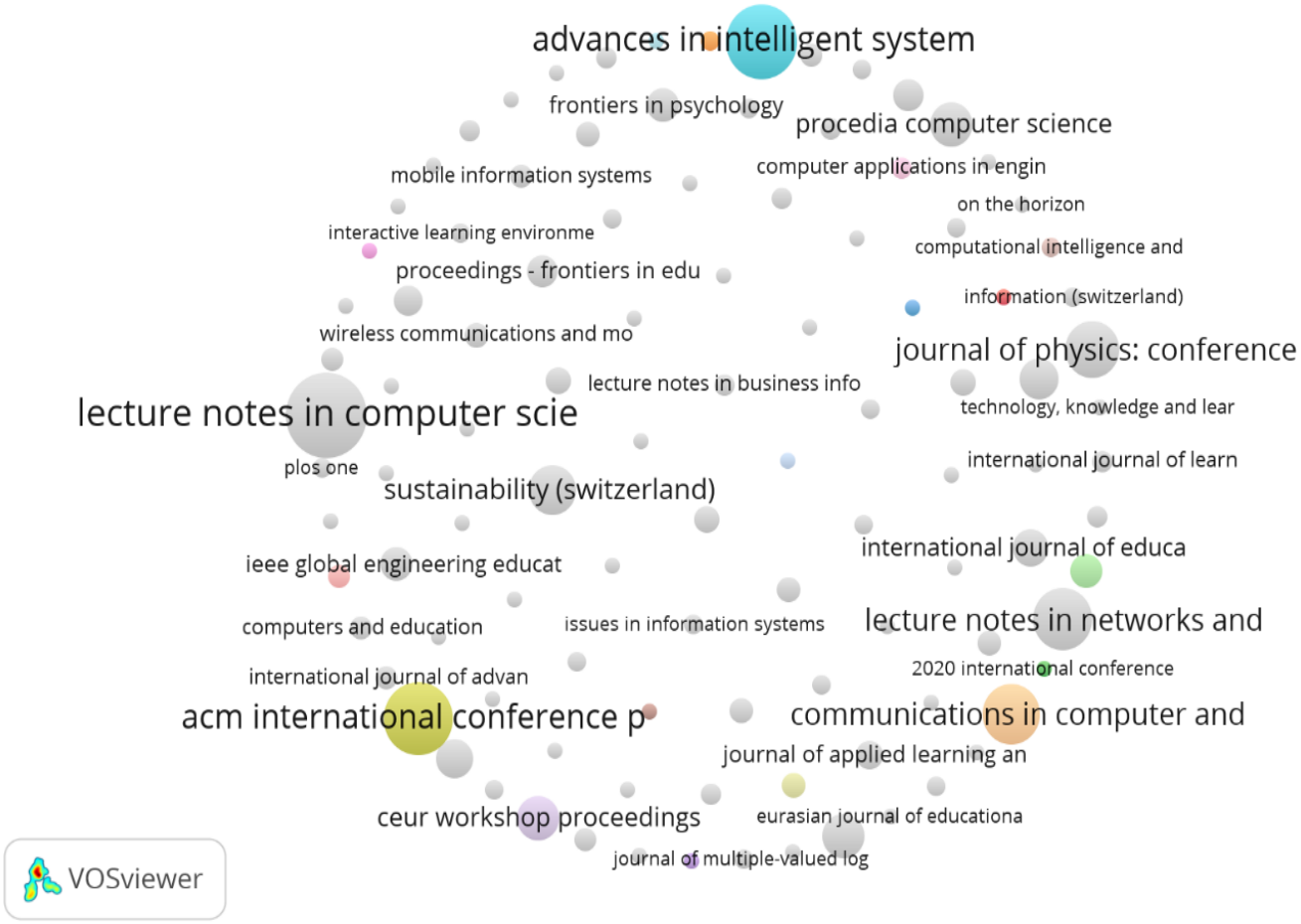

Figure 3. Networks Visualization View Main Journal Topic AI in Higher Education

3.3. Author References

By employing the VOSviewer co-authorship visualization model, the collaboration patterns among authors in the utilization of AI in higher education were analyzed. Based on 1,610 research documents published by 1,480 authors, using a minimum of 2 authors per document as a reference, the collaborative network of authors on AI in higher education was considered. Figure 4 illustrates an extensive author collaboration network. Authors with the most documents are: 1) Maphosa V, Maphosa M. 2) Alam A., Mohanty A. 3) Fomunyam K.G. 4) Jr. Additionally, other authors, on average, published only two articles on this topic. The highest citations from these authors are: 1) Rudolph J, Tan S, Tan S. 2) Sandu N., Gide E. 3) Yang X. 4) Xiao M, Yi H.

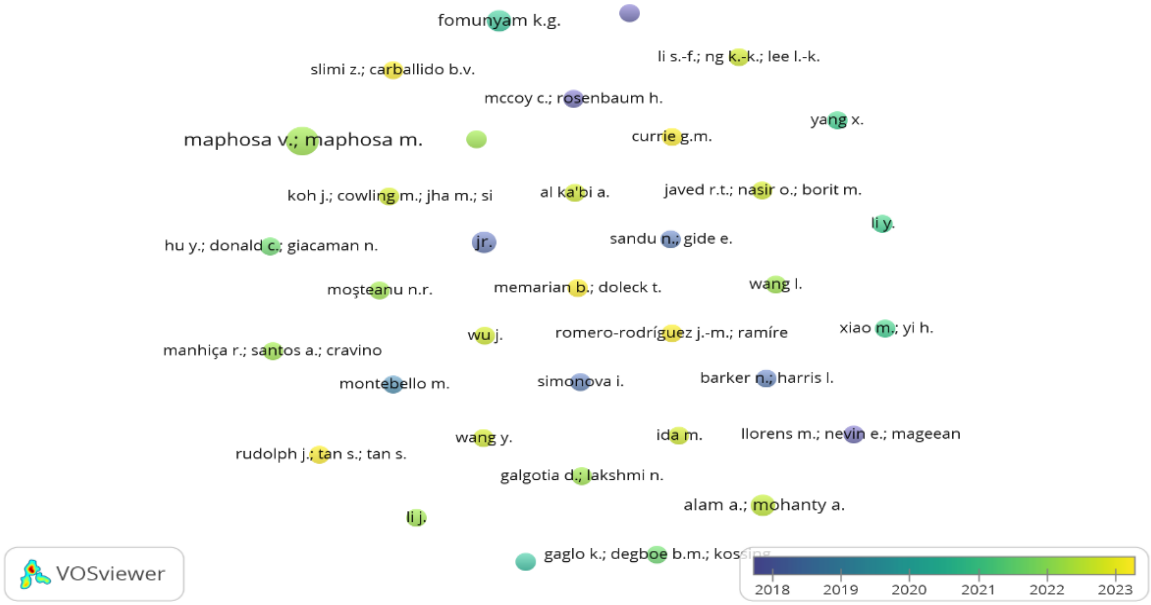

Figure 4. Network of AI Topic Article Writers in Higher Education

3.4. Keyword Analysis

We used VOSviewer to analyze keywords, specifically the author keywords from the 1610 articles analyzed. VOSviewer generated 8035 keywords, with a minimum occurrence set at 3, resulting in 1075. Figure 5 illustrates a network map of co-occurring keywords generated by VOSviewer. The distance between two nodes indicates the associative strength between nodes, with shorter distances indicating more robust relationships. The red cluster is the most significant, with 383 keywords focusing on data as the central theme. Data is operated using algorithms, analytics, and techniques to transform teaching and learning through AI. This cluster also emphasizes the use of AI in monitoring academic performance and decision-making based on existing data.

The yellow cluster comprises 339 keywords and depicts the use of AI to prepare students for more active learning. It reflects the trend of AI in higher education in e-learning and classroom settings. The blue cluster has 252 keywords and describes the application of AI to support learning delivery and curriculum. This cluster ensures the security of AI use in higher education and creates opportunities to develop new skills to ensure graduates are ready for the workforce.

The last green cluster, the smallest with 226 keywords, highlights research on developing AI-based applications in higher education on various platforms and their use by management and teaching staff in higher education institutions. This cluster indicates the use of AI technology systems as a driving force for AI growth in higher education. It also shows research on opportunities and challenges this sector faces, as well as innovations and solutions adopted for higher education, such as chatbots.

As seen, "decision-making" and "active learning" have been the research focus in the past decade. Density visualization map analysis indicates that this field is mature, with research conducted in clusters. Apart from these areas, this map shows that research extends to themes and areas yet to be explored, factors influencing the implementation of AI in higher education, and the foundations of AI application in higher education.

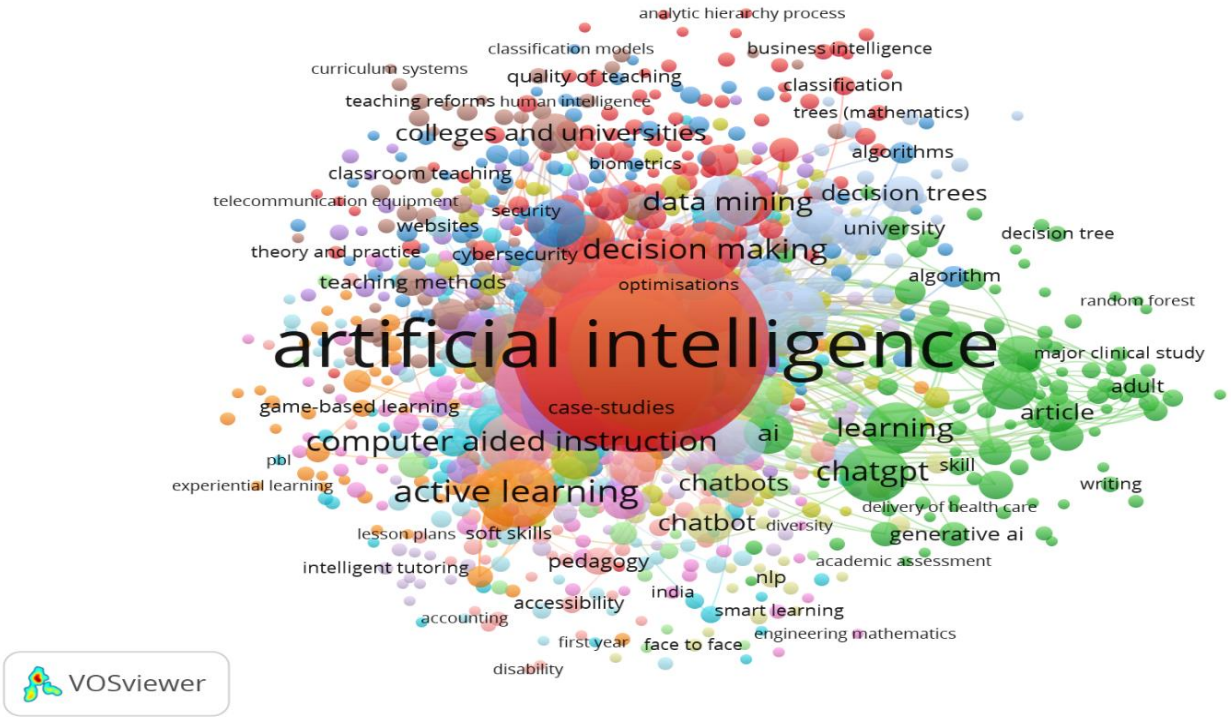

Figure 5. Keyword Occurrence Map of High-Frequency Terms in Titles and Abstracts

3.5. Discussion

This study indicates that AI research in higher education revolves around four themes – data as a catalyst for digital transformation, the development of artificial intelligence, the application of artificial intelligence in higher education, trends, jobs, and the future of higher education. This study contributes literature on the use of AI in HE, utilizing bibliometric analysis. Bibliometric analysis provides visual insights into AI in HE and contributes to new and ongoing research. The results show that computer science has been a leading field in recent decades. However, other subfields, such as medicine, engineering, natural language processing, education, and commerce, have emerged as significant application areas. AI research is multidisciplinary, encompassing traditional fields like computer science, physics, and astronomy. AI research in HE over the past ten years is depicted through clusters.

Keyword mapping indicates that the green cluster is related to processes, tools, skills, impacts, and changes produced. The yellow cluster relates to the use of AI to prepare students for the workforce. The blue cluster is related to implementation, experiments, capabilities, and interactions, while the red cluster depicts courses, concepts, factors, learners, and implications. Interest in AI in education has transformed the teaching and learning processes and supported students and teachers during the pandemic when face-to-face learning was not feasible. This indicates an increase in adopting adaptive learning technologies, virtual and augmented reality, analytics, data mining, and data-driven education.

The heat map shows that processes, skills, contexts, factors, courses and jobs, time, and impact are crucial focal points. One emerging trend in AI implementation in higher education is predictive analytics, which institutions use to enhance performance and competitiveness (Bowdre, 2020). The density map indicates the theme of educational process development. One relates to AI tools that help identify complex learning situations and improve learning

outcomes in institutions (Bhardwaj, 2019). Teaching bots are crucial to address challenges faced by HE, disrupting traditional face-to-face teaching. Institutions deploy robots to teach students and monitor class activities (Yu, 2020). Another way AI is used in higher education is indirectly through external frameworks and prosthetics supported by AI to alleviate age and disability limitations and enhance access to education (De Lange, 2015). Penetration of neurotechnology and advancements in neuroscience allow data collection from the human brain to support learning (Williamson, 2019). According to Bahadir (Bahadir, 2016), RS and AI predictions can accurately estimate a student's likelihood of completing or failing a subject. Automatic student recruitment will be a focus of AI implementation in the future.

Despite considerable attention given to bibliometric analysis, it has some limitations. We selected the Scopus database and omitted others like Web of Science and Google Scholar; therefore, our report may underestimate research index trends. Once again, only English-based papers were chosen, so some other studies were not included, leading to an underestimation of research. Other research materials, such as editorial comments, newspaper articles, and grey literature, are not included.

4. Conclusion

The current study aims to provide bibliometric analysis and topic modeling of the volume and trends in research on the implementation of AI in higher education (HE) from the Scopus database. This study expands on our earlier conference work, which provided an overview of AI research in HE, and this bibliometric analysis delves deeper to encompass the status, trends, principal contributors, and emerging hotspots. AI is revolutionizing education by reducing the teacher workload, individualized learning, intelligent tutors, profile creation and prediction, high-precision education, collaboration, and student tracking. AI assists educators in adopting effective teaching methods and identifying learning needs and patterns, enhancing learning outcomes and decision-making.

Using the PRISMA methodology, we initially selected 1840 articles based on our search criteria. Publications unrelated to the use of AI in HE, comments, editorial notes, and publications without keywords and not in English were excluded, leaving 610 articles for analysis. We used VOSviewer to conduct keyword analysis to answer our research questions. This study provides analysis, annual publication reporting, country analysis, and keyword analysis and explores research trends from 2014 to 2023.

The identified hotspots will receive global attention in the coming years due to the impact of AI on every aspect of human life, including education. Our study provides a global overview and holistic picture of the implementation of AI in HE. Our findings reveal that most publications focus on teaching and learning support, with limited implementation in the administrative aspects of higher education. The suggestions provided by the author, derived from the findings of this study, include:

1. Future research could focus on AI in admission and administration aspects, such as addressing student queries. The imbalance in research outcomes between the Global North and South requires attention.

2. The rapidly growing adoption of AI in high-tech fields necessitates continuous investigation into the current conditions, trends, and emerging areas to influence research.

3. Our research urges governments and organizations in developing countries to fund AI research in education, as students must work in AI-based jobs.

4. This study contributes to the AI research literature in the field of education from Indonesia. Future researchers are expected to be able to explore various variables that can influence the use of AI in higher education using both quantitative and qualitative approaches.

Declarations

Source of Funding

This study did not receive any grant from funding agencies in the public, commercial, or not-for-profit sectors.

Competing Interests Statement

The authors declare no competing financial, professional, or personal interests.

Consent for publication

The authors declare that they consented to the publication of this study.

Authors' contributions

Both the authors took part in literature review, analysis and manuscript writing equally.

Availability of data and material

All data pertaining to the research is kept in good custody by the authors.

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